Attorney's Docket No. 42390P10918

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	Examiner: **Lau, Tung S.**
Doron Orenstien and **Ronny Ronen**	Art Group: **2863**
Application No. 10/038,162	
Filed: January 2, 2002	
For: DETERMINISTIC POWER ESTIMATION FOR THERMAL CONTROL	

Mail Stop Appeal Brief - Patents
Commissioner for Patents
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Alexandria, VA 22313-1450

APPEAL BRIEF

Pursuant to 37 C.F.R. § 41.37, Applicants submit the following Appeal Brief for consideration by the Board of Patent Appeals and Interferences ("Board"). Applicants also submit herewith a check in the amount of $500.00 to cover the cost of filing this opening brief, as set forth in 37 C.F.R. § 41.20(b)(2). Please charge any additional amounts due or credit any overpayment to Deposit Account No. 02-2666.

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I. REAL PARTY IN INTEREST

Doron Orenstien and Ronny Ronen, the parties named in the caption, transferred their rights in that which is disclosed in the subject application through an assignment recorded March 6, 2002 (reel/frame number 012449/0210) to Intel Corporation of Santa Clara, California. Accordingly, Intel Corporation is the real party in interest.

II. RELATED APPEALS AND INTERFERENCES

There are no related appeals or interferences that will directly affect, be directly affected by, or have a bearing on the Board's decision in this appeal.

III. STATUS OF CLAIMS

Claims 28-46 are pending in this application. All claims stand rejected. Applicant seeks review of all rejected claims and asks the Board to overturn the rejections based on arguments presented in support of independent claims 28, 35 and 41, and dependent claim 30.

IV. STATUS OF AMENDMENTS

No amendments to the claims are outstanding or remain to be entered.

V. SUMMARY OF CLAIMED SUBJECT MATTER

The invention relates to thermal control for microprocessors. (*See* Field of the Invention.) Embodiments of the invention estimate microprocessor power usage so that a thermal control subsystem can activate throttling mechanisms to avoid high temperatures that can damage the microprocessor. (¶ 8). The power usage estimates are deterministic at a system and application level (¶ 10), so the non-deterministic behavior that plagues thermal-diode-based temperature management schemes can be avoided (¶¶ 4, 5, 10, 33-35).

Power estimates are made by a mathematical function that takes various collected data into account (¶¶ 26, 27). The data may be counts of the number of times certain functional units (such as a floating point processor and cache memory, ¶ 15) are

activated. The function may also factor in other parameters such as the processor's operating voltage and clock frequency (¶ 16). In some embodiments, counter data may be weighted by multiplying counts by weighting factors (¶ 29). Average power consumption may be calculated as a weighted sum over a number of previous estimates of power usage (¶ 31).

Since the power estimates are made based on discrete inputs such as counter values and voltage/frequency levels, they are deterministic: when the same application is executed on two identical machines, they will generate the same count value and have the same throttling behavior and performance (¶ 34). "Identical" machines that rely on thermal diodes for temperature control are not deterministic: the same benchmark program will provide different performance results because the timing of throttling activation will differ from machine to machine (¶ 33).

All three independent claims (28, 35 and 41) and one dependent claim (30) are specifically discussed in this appeal.

Independent claim 28 is an apparatus to count the number of times a functional unit of the apparatus is activated and to calculate a deterministic estimate of the apparatus's overall power consumption by a mathematical function that operates on the count (¶¶ 14, 15 and 34).

Dependent claim 30 refines the apparatus of claim 28 to include within the deterministic estimate of the overall power consumption, the operating voltage level and current clock frequency of the apparatus (¶¶ 16, 19-20, 30).

Independent claim 35 is a method of counting the number of times a functional unit of an integrated circuit is activated, and applying a mathematical function to generate a deterministic estimate of the overall power utilization of the integrated circuit based in part on the number of times the functional unit was activated (¶¶ 14, 15 and 34).

Independent claim 41 is a machine-readable medium containing instructions to cause a machine to perform operations comprising counting a number of times a first functional unit of the machine is activated and applying a mathematical function to generate a deterministic estimate of an overall power utilization of the machine, the mathematical function to accept as an input the count of activations of the first functional unit (¶¶ 14, 15, 34 and 36).

VI. GROUNDS OF REJECTION

Claims 28-40 stand rejected under 35 U.S.C. § 102(e) as anticipated by U.S. Patent No. 6,789,037 issued to Gunther *et al.* ("*Gunther*").

Claims 41-46 stand rejected under 35 U.S.C. § 103(b) as anticipated by U.S. Patent No. 5,719,800 issued to Mittal *et al.* ("*Mittal*").

VII. ARGUMENT

A. Overview of Cited References

1. U.S. Patent No. 6,789,037 to Gunther *et al.* ("*Gunther*")

Gunther teaches an integrated, on-chip thermal management system providing closed-loop temperature control of an IC device (*see* Abstract). A key feature of the system is one or more temperature sensors (Fig. 2, 222; col. 4, lines 60-62; col. 6, lines 51-52) to measure the temperature of the IC die. *Gunther* describes an embodiment where an up-down counter counts the number of system clock pulses that occur when the temperature sensor indicates (through a comparator) that the die temperature is above or below a trip point (*see* col. 7, lines 44-56). (The counter counts up when the temperature is above the trip point, and down when the temperature is below the trip point.) The output of the temperature sensor, possibly filtered through an analog or digital filter (*see* col. 7, lines 16-17, 33-36, 44-45), or processed in some other way, controls a power modulation element to reduce the power dissipation of the IC and lower its die temperature (*see* col. 8, lines 9-16).

Gunther's system is explicitly described as susceptible to sensor inaccuracies (*see* col. 7, lines 8-10) and noise (col. 7, lines 24-30). Therefore, it fails to perform deterministically, as Applicants discuss in greater detail below.

2. U.S. Patent No. 5,719,800 to Mittal *et al.* ("*Mittal*")

Mittal describes a system to monitor the recent utilization levels of functional units within an IC and calculate an average duty cycle for each unit over its recent operating history (*see* Abstract). Then, if the duty cycle exceeds a sustainable maximum level, functional units can be throttled back to a low-power mode of operation to avoid reliability, heat dissipation or power supply problems (*see* col. 4, lines 19-27).

Mittal does not, however, calculate a deterministic estimate of overall power utilization, nor does it make its throttling decisions based on such an estimate.

B. Claims Rejected Under 35 U.S.C. § 102(e)

1. Regarding Claims 28-40

The Examiner rejected claims 28-40 under 35 U.S.C. § 102(e) as anticipated by *Gunther* (*supra*). A common theme of the Applicants' arguments in support of these claims concerns the definition of the word "deterministic," as used in independent claims 28 and 35. Applicants previously argued that the word describes a system whose "time evolution can be predicted exactly." (*The Free Online Dictionary of Computing*, © 1993-2004 by Denis Howe.) Other sources provide similar definitions. For example, the British Ministry of Defence provides this glossary entry on its website: "[p]ertaining to a process, model, simulation or variable whose outcome, result, or value does not depend upon chance. Contrast with: stochastic," while the American Meteorological Society suggests "governed by and predictable in terms of definite laws, such as dynamic equations." The definitions often mention that randomness or unpredictability are not qualities associated with a deterministic system.

The Examiner offered a different definition of "deterministic" in rejecting these claims: "a theory or doctrine that acts of the will, occurrences in nature, or social or psychological phenomena are causally determined by preceding events or natural laws" (*Merriam-Webster Online Dictionary*). Applicants are unsure of the relevance of "acts of the will" or "social or psychological phenomena" to the field of microelectronic circuits, and respectfully suggest that other definitions provide a more useful foundation for interpreting the rejected claims.

In the systems described and claimed by Applicants, consistency and repeatability are important qualities. One system, given the same input and identical initial conditions, should produce the same result within the same time, and a second, identical system should perform the same. Here, "same input" and "identical initial conditions" refer to practically achievable conditions, and not to merely theoretically possible conditions. For reasons discussed in greater detail below, *Gunther* does not describe a deterministic system. This difference alone is adequate basis for the Board to overturn the rejections of claims 28-40.

2. Regarding Claims 28 and 35

Claim 28 is drawn to an apparatus comprising a first counter to count a number of times a first functional unit of the apparatus is activated, and a processing unit to apply a mathematical function to yield a deterministic estimate of an overall power consumption, the mathematical function to accept inputs including a value from the first counter. Claim 35 recites a method to generate a deterministic estimate of an overall power utilization of an integrated circuit, comprising counting a number of times a first functional unit is activated and applying a mathematical function to generate the estimate. Both claims contain the idea of calculating a deterministic power estimate based on a count of activations of a functional unit.

Gunther has an apparatus including a counter to count the number of times a first functional unit is activated: at col. 7, lines 44-56, a counter counts the number of system clock pulses that occur during a logic state at a comparator, which in turn compares a temperature sensor signal with a reference voltage. However, Applicants have been unable to locate a mathematical function being applied to the value in the counter. Assuming for the moment that the function could be as simple as $f(x) = x$, though, Applicants observe that the counter's value is deterministic only if one looks no further back than the comparator's *output.*

It is, of course, possible to count the exact number of system clock pulses during which the comparator's output is high or low, but there is no correlation between that count and an estimate of an overall power consumption of an apparatus. A link between the count and the system's power utilization can be established only by considering the comparator's *input*: a temperature sensor on the semiconductor die. Furthermore, one must assume that there is a connection between die temperature and power utilization that can be expressed in by a mathematical function. Unfortunately, by expanding the examination of *Gunther*'s system to include the comparator's input, the count becomes non-deterministic; and in any case, the reference discloses no mathematical relationship between temperature and power utilization.

Gunther's count is non-deterministic because it depends on variables such as the ambient temperature of the system's environment, thermal transfer away from the semiconductor die, and intrinsic properties of the semiconductor itself (which can vary from unit to unit). Even if these conditions were assumed to be exactly known,

controllable and reproducible (which, of course, they are not), *Gunther* explicitly acknowledges that "small voltage spikes [...] may cause the comparator to signal that the die has reached the trip point when, in fact, the die has not yet reached this temperature or, likewise, cause the comparator to signal that the die is below the trip point when, in fact, the die is above this temperature." (*See* col. 7, lines 24-29.)

In other words, random noise and environmental characteristics that cannot be precisely determined or controlled factor into the value from *Gunther*'s counter, so neither the value nor any quantity calculated by a mathematical function from the value can be predicted or repeated from test to test or system to system. Thus, the best that can be said of the counter value is that it is stochastically correlated with die temperature. This is two steps removed from the material of claims 28 and 35: first, the counter value is not deterministic, and second, the value is not an estimate of an overall power consumption. Consequently, *Gunther* fails to teach at least a processing unit to apply a mathematical function to yield a deterministic estimate of an overall power consumption, as claim 28 requires; and the method of doing the same, as recited in claim 35. The Board should overturn the rejection of these claims.

3. Regarding Claim 30

Claim 30 refines the apparatus of claim 28, requiring that the mathematical function to yield a deterministic estimate of overall power consumption also accept as additional inputs an operating voltage level of the apparatus and a current clock frequency of the apparatus. Even assuming that *Gunther*'s non-deterministic temperature-sensor/counter combination reads on the base claim's counter and processing unit, the operating voltage and clock frequency of *Gunther*'s processor never factor into the counter value. Thus, although *Gunther* describes changing the microprocessor's supply voltage (*see* col. 8, lines 52-54) and lowering the system clock frequency (*see* col. 8, lines 65-67) to reduce the microprocessor's power consumption, these are *effects* that occur *after* a high temperature has been detected, rather than *inputs* to the sensor that that detects the high temperature.

The Examiner suggests that the "Programmable Voltage" 224 and "Reference Voltage" 226 in *Gunther*'s Fig. 4 are the claimed operating voltage, but *Gunther*'s description at col. 5, lines 33-35 makes clear that these elements are simply parts of a temperature sensor, and not the same as the microprocessor's operating voltage level or

"supply voltage (V_{cc})." As to the indicated elements of Fig. 6, these seem to have no connection with either the processor's current clock frequency or the estimation of an overall power consumption. Instead, decision blocks 430 and 460 compare the detected temperature with high and low thresholds (T_{trip} and T_{untrip}), and step 470 turns off any active throttling mechanisms.

Applicants respectfully submit that the rejection of claim 30 confuses *Gunther*'s effect on its processor's operating voltage and clock frequency with the cause that may lead to that effect (excessive substrate temperature). The Board should correct the confusion by overturning this rejection.

C. Claims Rejected Under 35 U.S.C. § 102(b)

The Examiner rejected claims 41-46 under 35 U.S.C. § 102(b) as anticipated by U.S. Patent No. 5,719,800 issued to Mittal *et al.* ("*Mittal*"). Although *Mittal*'s system to monitor functional unit utilization and reduce integrated circuit ("IC") power consumption bears some superficial resemblances to Applicants' system for deterministic power estimation for thermal control, it differs in certain key respects. For the reasons discussed below, Applicants disagree that *Mittal* discloses all the limitations of the rejected claims, as required for such a rejection.

1. Regarding Claim 41

Claim 41 is drawn to a machine-readable medium containing instructions to cause a machine to perform certain operations, including counting a number of times a first functional unit of the machine is activated and applying a mathematical function to generate a deterministic estimate of an overall power utilization of the machine, the mathematical function accepting as an input the number of times the first functional unit was activated. *Mittal*'s system counts the number of times various functional units of an integrated circuit are activated (*see, e.g.*, col. 6, lines 8-26), but the counts are not used to generate a deterministic estimate of overall power utilization. Instead, *Mittal* teaches using the counts to calculate a different value, functional-unit utilization (also called "activity level" and "duty cycle." *See* col. 5, lines 30-37.)

The Examiner indicates a portion of *Mittal*'s background as teaching or suggesting the generation of a deterministic estimate of an overall power utilization (allegedly, col. 1, lines 28-67), but that section merely describes part of the process of

designing a new system, wherein one might be interested in estimating typical power consumption to project battery life under a typical application load as modeled by a benchmark sequence of operations (*see* col. 1, lines 55-67). This is different from counting a number of times a functional unit is activated and applying a mathematical function to generate a deterministic estimate of an overall power utilization at least because *Mittal*'s estimated "typical power consumption" is based on a measurement or estimate of power consumed by the IC in performing the benchmark suite of typical operations, and not on a count of the number of times a functional unit is activated.

There is no connection (via mathematical function or otherwise) between this "estimate" of typical power consumption and the activity level or duty cycle that serves as the basis for *Mittal*'s later decisions about functional unit throttling. Since *Mittal* fails to disclose applying a mathematical function to generate a deterministic estimate of an overall power utilization of the machine, based on a count of the number of times a first functional unit was activated (as claim 41 requires), the Board should overturn the rejection of this claim.

CONCLUSION

Based on the foregoing, the Board should **overturn** the rejection of claims 28-46 and hold that all of the claims currently pending in the application under review are allowable.

Dated: June 27, 2005

Respectfully submitted,
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VIII. CLAIMS APPENDIX

The claims involved in this appeal are presented below.

28. (Previously Presented) An apparatus comprising:

a first counter to count a number of times a first functional unit of the apparatus is activated;

a processing unit to apply a mathematical function to yield a deterministic estimate of an overall power consumption, the mathematical function to accept inputs including a value from the first counter.

29. (Previously Presented) The apparatus of claim 28, wherein

a first weighting factor is associated with the first counter;

a second counter having a second weighting factor is provided, the second counter to count a number of times a second functional unit of the apparatus is activated; and

the mathematical function accepts as additional inputs the first weighting factor, the second weighting factor and a value from the second counter.

30. (Previously Presented) The apparatus of claim 28, the mathematical function to accept as additional inputs an operating voltage level of the apparatus and a current clock frequency of the apparatus.

31. (Previously Presented) The apparatus of claim 28, further comprising:

at least one throttle to alter the overall power consumption of the apparatus, wherein

the at least one throttle is activated if the deterministic estimate of an overall power consumption exceeds a first threshold power level, and

the at least one throttle is deactivated if the deterministic estimate of an overall power consumption falls below a second threshold power level.

32. (Previously Presented) The apparatus of claim 31 wherein the first threshold power level and the second threshold power level are the same.

33. (Previously Presented) The apparatus of claim 28 wherein the first functional unit is one of a floating point unit, a cache unit, and an instruction decoding unit.

34. (Previously Presented) The apparatus of claim 28 wherein the mathematical function accepts as an additional input at least one previous deterministic power consumption estimate.

35. (Previously Presented) A method comprising:

counting a number of times a first functional unit of an integrated circuit is activated and

applying a mathematical function to generate a deterministic estimate of an overall power utilization of the integrated circuit, the mathematical function accepting as an input the number of times the first functional unit was activated.

36. (Previously Presented) The method of claim 35, further comprising:

adjusting the number of times the first function unit was activated by a first scaling factor;

counting a number of times a second functional unit of an integrated circuit is activated;

adjusting the number of times the second functional unit was activated by a second scaling factor; and

supplying the adjusted number of times the second functional unit was activated as an additional input to the mathematical function.

37. (Previously Presented) The method of claim 35, further comprising:

supplying an operating voltage level and a current clock frequency of the integrated circuit as additional inputs to the mathematical function.

38. (Previously Presented) The method of claim 35, further comprising:

reducing the operating voltage level of the integrated circuit if the estimate of the overall power utilization exceeds a first threshold, and

increasing the operating voltage level of the integrated circuit if the estimate of the overall power utilization falls below a second threshold.

39. (Previously Presented) The method of claim 35, further comprising:

reducing the clock frequency of the integrated circuit if the estimate of the overall power utilization exceeds a first threshold, and

increasing the clock frequency of the integrated circuit if the estimate of the overall power utilization falls below a second threshold.

40. (Previously Presented) The method of claim 35 wherein the first functional unit is one of a floating point unit, a cache unit, and an instruction decoding unit.

41. (Previously Presented) A machine-readable medium containing instructions that, when executed by a machine, cause the machine to perform operations comprising:

counting a number of times a first functional unit of the machine is activated, and

applying a mathematical function to generate a deterministic estimate of an overall power utilization of the machine, the mathematical function accepting as an input the number of times the first functional unit was activated.

42. (Previously Presented) The machine-readable medium of claim 41 containing instructions that, when executed by the machine, cause the machine to perform additional operations comprising:

adjusting the number of times the first function unit was activated by a first scaling factor;

counting a number of times a second functional unit of the machine is activated;

adjusting the number of times the second functional unit of the machine was activated by a second weighting factor; and

incorporating the adjusted number of times the second functional unit was activated into the estimate of the overall power utilization.

43. (Previously Presented) The machine-readable medium of claim 41 containing instructions that, when executed by the machine, cause the machine to perform additional operations comprising incorporating an operating voltage level of the machine and a current clock frequency of the machine into the estimate of the overall power utilization.

44. (Previously Presented) The machine-readable medium of claim 41 containing instructions that, when executed by the machine, cause the machine to perform

additional operations comprising averaging the estimated power utilization with at least one previously-generated estimated power utilization.

45. (Previously Presented) The machine-readable medium of claim 41 containing instructions that, when executed by the machine, cause the machine to perform additional operations comprising:

reducing an operating voltage level of the machine if the estimated overall power utilization is above a first threshold; and

increasing the operating voltage level of the machine if the estimated overall power utilization is below a second threshold.

46. (Previously Presented) The machine-readable medium of claim 41 containing instructions that, when executed by the machine, cause the machine to perform additional operations comprising:

reducing a clock frequency of the machine if the estimated overall power utilization is above a first threshold; and

increasing the clock frequency of the machine if the estimated overall power utilization is below a second threshold.

IX. Evidence Appendix

No evidence is submitted with this appeal.

X. Related Proceedings Appendix

No related proceedings exist.